AMERICAN SOCIETY OF HEATING, REFRIGERATING

AND AIR-CONDITIONING ENGINEERS, INC.

1791 Tullie Circle, NE Atlanta, GA 30329 404-636-8400

TC/TG/TRG MINUTES COVER SHEET

(Minutes of all meetings are to be distributed to all persons listed below

within 60 days following the meeting.)

TC/TG/TRG NO. TG4.SBS DATE: 14 November6 1997

TC/TG/TRG TITLE: Smart Building Systems

DATE OF MEETING: 1 July 97 LOCATION: Boston

Members Present	Appt	Members Absent	Appt	Ex-Officio Members and Additional Attendance
George Kelly	96-98	Mark Bailey	96-00	Marty Applebaum
John Mitchell	96-00	Barry Bridges	96-97	Jean-Pascal Bourdouxhe
Les Norford	96-98	Arthur Dexter (int'l member)	96-00	Michael Brambley
Jim Braun	96-00	Ira Goldschmidt	96-97	Michael Brandemuehl

Philip Haves (int'l member)	96-00	Patrick O'Neill	96-99	Natascha Castro
Carol Lomonaco	96-99	Peter Simmonds	96-97	Charles Claar
Steve Blanc	96-99	Nebil Ben-Aissa (CM)	96-	Paul Duff
Ron Kammerud	96-99	Kirk Drees (CM)	96-	Barrett Flake
Michael Kintner-Meyer	96-97	Brian Kammers (CM)	96-	James Gartner
Doug Nordham	96-98	Tim Ruchti (CM)	96-	Rich Hackner
John Seem (CM)	96-00	Greg Schoenau (CM)	96-	Winston Hetherington
John House (CM)	96-			Richard Kelso
J. Carlos Haiad (CM)	96-			Curt Klaassen
David Kahn (CM)	96-			Hanjin Miao
Jim Winston (CM)	96-			Kent Montgomery
				Cher Nicastro

				Bob Old
				John Phelan
				Barry Reardon
				Todd Rossi
				Jeff Rutt
				Pornsak Songkakul
				Gene Strehlow
				Steve Yang
				Jim Yi

DISTRIBUTION:

ALL MEMBERS OF TC/TG/TRG

TAC CHAIRMAN: Erv L. Bales

TAC SECTION HEAD: Jeffrey Biskup

ALL COMMITTEE LIASONS AS SHOWN ON TC/TG/TRG ROSTERS:

Program: Thomas D. Logan Manager Of Technical Services: Claire B. Ramspeck

Research: Carl F. Spreich Manager Of Research: William W. Seaton

Standards: Waller S. Clements Manager Of Standards: Jim L. Heldenbrand

ADDITIONAL DISTRIBUTION: Visitors listed above

ASHRAE TC ACTIVITIES SHEET

DATE: 11 November 97

TG NO. TG4.SBS TC TITLE: Smart Building Systems

CHAIR: G. Kelly VICE CHAIR: J. Mitchell

TG Meeting Schedule

Location, past 12 mo.	Date	Location, next 12 mo.	Date
Philadelphia	1/26/97	San Francisco	1/20/98
Boston	7/1//97	Toronto	6/24/98

TG Subcommittees

Subcommittee	Chair
Fault Detection/Diagnosis	J. Seem
Applications	J. House

Utility/Building Interface	S. Blanc
Research	J. Braun
Program	C. Lomonaco

Research Projects

1011-RP Utility/EMCS Communication Protocol Requirements

1020-TRP Demonstration of Fault Detection and Diagnostic Methods in a Real Building

1043-TRP Fault Detection and Diagnostic Requirements and Evaluation Tools for Chillers

Long Range Research Plan and Additional Work Statements

Rank	Title	W/S Written ?	TG Approved ?	To RAC ?
1	Fault Detection and Diagnostic Requirements and Evaluation Tools for Chillers *	Yes	Yes	Yes
2	Integrated Building Services - Performance and Performance Measurements	Yes	No	No
3	Distributed and Hierarchical Fault Detection and Diagnosis of HVAC Systems	No	No	No
4	Optimizing EMCS Architecture in BACnet Speaking Systems	No	No	No

5	Development and Evaluation of Fault Detection and Diagnostic Methods for Chillers	No	No	No
6	Development of Fault Detection and Diagnostics for Sensor Failures	No	No	No

* Item #1 on the LRRP was approved by RAC subsequent to the TG meeting.

Handbook Responsibilities - none

Standards Activities - none

Technical Papers from Sponsored Research - none

TG Sponsored Symposia (past 3 years, present, planned)

Title	**Date (Given or Planned)**
HVAC System Fault Detection And Diagnosis (Kelly)	Philadelphia, 1/97
Fault Detection and Diagnosis Using Real Building Operating Data (Haves and Ahmed; TG4.SBS lead with TC 1.4 as co-sponsor)	Toronto, 6/98
Controlling Outdoor Air Ventilation for 62-1989 (Ganesh; TC 1.4 lead with TG4.SBS as co-sponsor)	Toronto, 6/98

TG Sponsored Seminars (past 3 years, present, planned)

Title	**Date** **(Given or Planned)**
The Utility/Building Interface: Redefining an Old Relationship (Blanc)	Boston, 6/97
BACnet in the Real World (Bushby; TC 1.4 lead with SSPC 135 BACnet and TG4.SBS as co-sponsors)	Boston, 6/97
Benefits of Integrating HVAC with Non-HVAC Systems (Newman; TC 1.4 lead with SSPC 135 BACnet and TG4.SBS as co-sponsors)	San Francisco, 1/98
Impact of Electromagnetic Interference on Control Systems and Global Standards (Coogan; TC 1.4 lead with TG4.SBS and TC 1.9 as co-sponsors)	San Francisco, 1/98
The Delivery of New Energy Services under Electric Industry Deregulation (Nordham; TG4.SBS lead with TC 1.4 as co-sponsor)	San Francisco, 1/98
Automated Response To Real Time Pricing (Kammerud)	San Francisco, 1/98
The Latest Control Communications Technologies (Gartner; TC 1.4 lead with TG4.SBS as co-sponsor)	Toronto, 6/98

TG Sponsored Forums (past 3 years, present, planned)

Title	**Date** **(Given or Planned)**

What Are The Priorities For On-Line HVAC Fault Detection And Diagnosis? (Haves)	Philadelphia, 1/97
Exactly What Do Smart Buildings and Control Systems Mean Today? (Newman and Kelly; TC 1.4 lead with TG4.SBS and TCs 1.5 and 4.6 as co-sponsors)	Boston, 6/97
Now That We Have the BACnet Standard Protocol, are DDC Programming Language and Application Standards Next? (Nesler; TC 1.4 lead with SPC 135 BACnet and TG4.SBS as co-sponsors)	San Francisco, 1/98
Occupant Driven Interactive Building Control (Bridges; TG4.SBS lead with TC 1.4 as co-sponsor)	San Francisco, 1/98
CAB and BACnet Similarities and Dissimilarities (Newman; TC 1.4 lead with SPC 135 BACnet and TG4.SBS as co-sponsors)	Toronto, 6/98

Journal Publications (past 3 years, present, planned)

Title	**When published**
None	

Minutes summary and activities sheet submitted by: Les Norford—TG4.SBS Secretary

TG4.SBS Minutes

Tuesday, July 1, 1997 -- Boston

Roll Call, Introductions, Announcements

Chairman Kelly called the meeting to order at 3:37 p.m and asked for a roll call and introductions. Ten of 16 voting members were present: Kelly, Mitchell, Norford, Braun, Haves, Lomonaco, Blanc, Kammerud, Kinter-Meyer, Nordham.

The agenda was distributed. The call to meeting and agenda are found in Appendix A.

A motion was made (Mitchell) and seconded (Nordham) to accept the minutes from the January 1997 meeting. The motion was approved unanimously.

Fault Detection and Diagnosis Subcommittee Report (Braun)

Braun, the acting subcommittee chair for this meeting, reported that the subcommittee meeting was primarily devoted to a draft work statement on **FDD Requirements and Evaluation Tools for Chillers (Research Priority Item #1)**. Braun reviewed the work statement, deliverables for which are chiller models and data sets of normal and faulty behavior. Targeted equipment was broadened to include screw as well as centrifugal chillers, because the cost of purchasing a centrifugal chiller may inhibit potential bidders. The third task, to develop a simulation model, was tightened to emphasize that prediction of trends is more important than accurate prediction of actual performance. Motion was made (Braun) and seconded (Mitchell) to recommend approval of this work statement by RAC; the motion was passed by a vote of 10-0-0, chair voting. The work statement as sent to RAC is Appendix H of the minutes.

Program and research plans were deferred for discussion as part of the Program and Research Subcommittee chairs' reports.

Haves briefly reviewed the mission and progress of IEA Annex 34, "Computer-Aided Evaluation of HVAC System Performance: the Practical Application of Fault Detection and Diagnosis." This Annex focuses on practical problems in implementing FDD techniques in real buildings. Researchers in partnership with industry are performing the work. The third meeting of the Annex will be held at the University of Colorado in Boulder, September 29-October 1, 1997. Kelly invited those interested and willing to work to consider participation in the U.S. contingent.

Minutes of the subcommittee meeting are in Appendix B.

Applications (House)

House announced that the work statement entitled **"Demonstration of Fault Detection and Diagnostic Methods in a Real Building**," approved by the TG via email ballot after the January 1997 meeting, has been approved by RAC and is designated 1020-TRP. It will go out for bid this Fall. Kammerud reviewed a work statement on **Integrated Building Services - Performance and Performance Measures (Research Priority Item #2)**. This intent of the work is to understand the costs and benefits of integration across major building systems. Kammerud will continue to refine the work statement by making the tasks more specific.

Applebaum provided an update of the Philip Burton Federal Office Building project in San Francisco, a 1.4 million square foot office building and courthouse managed by GSA that is a demonstration site for a variety of energy-efficiency improvements, controls upgrades and BACnet communications. The project is on schedule and should be completed in December 1997. Applebaum stated that GSA should be able to accommodate a small number of visitors to the building as part of the January 1998 ASHRAE meeting in San Francisco, and that the Golden Gate chapter is giving consideration to hosting more formal tours.

House provided information about the Energy Resource Station (ERS) at the Iowa Energy Center. This building, a new facility with laboratory-like measurement and testing capabilities, or a facility comparably equipped must be used for the work specified in 1020-TRP. The TRP states that ERS has donated two months of building access and substantial engineer (80 hours) and technician (240 hours) time. Curt Klaassen stated that data access to the HVAC systems, with level of access controlled by ERS, can be obtained with inexpensive software.

Minutes of the subcommittee meeting are in Appendix C.

Utility/Building Interface (Blanc)

Blanc stated that the seminar sponsored by TG4.SBS, "Utility/Building Interface: Redefining an Old Relationship," was a success and that issues raised in the seminar provided ideas for future programs. In particular, facility and property managers face many challenges, not just energy services and deregulation of the electric utility industry. Charlie Claar of the International Facilities Managers Association will asked to chair a seminar for a future meeting that would present customers' views of deregulation.

Blanc will collate ideas shared at the subcommittee meeting about the purpose of the subcommittee. The minutes of the subcommittee meeting are in Appendix D.

It was moved (Norford) and seconded (Mitchell) that TG4.SBS recommend that RAC award 1011-TRP to SAIC. This TRP is titled **"Utility/EMCS Communication Protocol Requirements"**. The motion passed 8-0-0 chair voting, with 2 members of the TG bidding and therefore not voting. The PMSC consists of Blanc, Bushby (TC 1.4), Kelly, Nordham, and Norford (chair).

Research Subcommittee (Braun)

Braun presented the TG's Long-Range Research Plan (Appendix G):

1. Fault Detection and Diagnostic Requirements and Evaluation Tools for Chillers - WS approved
2. Integrated Building Services - Performance and Performance Measurements - WS underway
3. Distributed and Hierarchical Fault Detection and Diagnosis of HVAC Systems - Rossi and Brambley to continue draft started by Haves
4. Optimizing EMCS Architecture in BACnet Speaking Systems

5. Development and Evaluation of Fault Detection and Diagnostic Methods for Chillers - the second phase of the chiller FDD project
6. Development of Fault Detection and Diagnostics for Sensor Failures - topic identified by Haberl and concerns analytic redundancy

For the next meeting, Haves will write a one-page summary for a new item, focused on system-level diagnostics.

It was moved (Braun) and seconded (Mitchell) that TG4.SBS approve the long-range research plan. The vote was 10-0-0, chair voting, in favor.

Blanc provided to Braun a copy of a work statement drafted by TC 9.9 (Commissioning) and concerned with tools for minimizing operating and maintenance costs. TCs 1.7 and 1.8 are interested in this work statement as well.

Program Subcommittee (Lomonaco)

Lomonaco presented the program for the upcoming meetings in San Francisco, Toronto, Chicago and Seattle. The program for San Francisco and Toronto is included in the summary sheet at the beginning of the minutes and the Program Subcommittee Report in Appendix E. It was moved (Lomonaco) and seconded (Kintner-Meyer) that TG4.SBS approve the program. The motion passed via a unanimous voice vote.

New Business

Earlier in the meeting, Jeff Biskup, the TAC section 4 head, noted that ASHRAE is considering more overlap of program with TC/TG meetings, specifically in a 1:45-3:45 slot on Sunday, Monday and Tuesday, and is also considering scheduling TC/TG meetings on Saturday. TG members strongly endorsed a protest by the TG, in response to Kelly's query. It was noted that there are many more seminars than symposia (45 and 17 at Boston) and was suggested that ASHRAE limit the ratio and impose higher quality control standards on seminars. Saturday TC/TG meetings were considered undesirable because Friday would become a travel day and standing committees already meet on Saturday. Kelly will summarize the discussion on the chair's summary sheet.

Kelly asked whether members favored converting from a TG to a TC, on the basis of the strength of the program and research already established by the TG and the prospects for significant work in the utility/building area for the next 10 years. It was noted that the TG distinguishes itself from TC 4.6 due to its focus on functional integration, utility/building interfaces, and FDD, and that there is no program overlap with TC 4.6. TC 1.4 coordinates with TG4.SBS in a complementary manner, and both are dynamic and provide a home for active members. Kelly asked for individual comments from voting members and all were in favor. A formal vote was subsequently held by email (see addendum).

Kelly announced that the November ASHRAE Journal will have a building-automation theme and that there is a thermal envelope conference in December.

Adjourn

The meeting was adjourned at 5:47 p.m.

Addendum - Poll To Convert from a Technical Group to a Technical Committee

An email ballot was conducted in September on a motion to recommend to TAC that TG4.SBS be converted to a Technical Committee. The vote was 16-0-0, chair voting. Kelly forwarded the results to Biskup, TAC section 4 head.

Appendices

A. Call to Meeting and Agenda
B. FDD Subcommittee Report
C. Applications Subcommittee Report
D. Building/Utility Interface Subcommittee Report
E. Program Subcommittee Report
F. List of Subcommittee Attendees
G. Long-Range Research Plan
H. FDD Requirements and Evaluation Tools for Chillers

Appendix A. Call to Meeting and Agenda

Reply to: George E. Kelly

Room B114 Bldg. 226

NIST

Gaithersburg, MD 20899

(George.Kelly@nist.gov)

May 12, 1997

Dear TG4.SBS Member,

International Member,

Corresponding Member, or

Visitors to the TG Meeting in Philadelphia

The Task Group on Smart Building Systems, TG4.SBS, and its subcommittees will meet in Boston according to the following schedule:

TG 4.SBS Fault Det. & Diagnostic Sub. Sunday 2:30-3:30pm Boston Marriott

TG 4.SBS Applications Sub. Sunday 3:30-4:30pm Boston Marriott

TG 4.SBS Utility/Bldg. Interface Sub. Sunday 4:30-5:30pm Boston Marriott

TG 4.SBS Program Sub. Sunday 5:30-6:30pm Boston Marriott

TG 4.SBS Smart Building Systems Tuesday 3:30-5:30pm Boston Marriott

Please consult your ASHRAE Program Booklet for meeting room locations. Also, **please note that the full TG meeting will be on Tuesday**, instead of Sunday. This change is in response to an Email poll conducted after the Philadelphia meeting in which members overwhelmingly stated their preference (15-2-1) to have the full TG meeting moved to Tuesday.

We currently have one Tentative Research Project, TRP - 1011, (entitled "Utility/EMCS Communication Protocol Requirements") out for bid. With luck, we should be in a position to select a contractor at our Boston meeting. We have another Work Statement, entitled "Demonstration of Fault Detection And Diagnostic Methods in A Real Buildings", that has been submitted to Bill Seaton for consideration by R&T's PMS subcommittee in Boston. Two or three other Research Work Statements are under development. Hopefully, some of these will be far enough along to be distributed and discussed at the various subcommittee meetings. Our 1998-99 Research Plan also must be revised in Boston.

The TG is sponsoring two program sessions in Boston that I encourage all of you to attend. They are:

Seminar 35, "The Utility/Building Interface: Redefining and Old Relationship"

10:15 a.m. - 12:15 p.m., Tuesday 7/1 (See ASHRAE Program Booklet for meeting room.)

Forum 30, "Exactly What Do Smart Buildings and Control Systems Mean"

8:00 a.m. - 8:50 a.m., Wednesday 7/2 (See ASHRAE Program Booklet for meeting room.)

Below is a draft agenda for the full TG4.SBS committee meeting in Boston. Please come prepared to: participate in one or more of the subcommittee meetings, discuss the different Research Work Statements and the Research Plan, accept responsibility for developing new work statements, and help plan future program sessions for San Francisco and beyond. As I mentioned at previous TG meetings, participation is the key to staying/becoming a TG member.

I am looking forward to seeing you in Boston.

Sincerely,

George E. Kelly

Chairman, TG4.SBS

cc: James Porter, TAC Chairman

Terry Townsend, TAC Section 4 Head

Carl Speich, R&T Research Liaison

Claire Ramspeck, Staff Liaison

Bill Seaton, Manager of Research

ASHRAE TG4.SBS

Smart Building Systems

1997 Annual Meeting, Boston

DRAFT AGENDA

Location: Boston Marriott (See ASHRAE Program Booklet for meeting room.)

Date: Tuesday, July 1, 1997

Time: 3:30 - 5:30 p.m.

1. Roll call and introductions

2. Approval of Minutes from Philadelphia

3. Announcements

4. FDD Subcommittee Report (John Seem)

Draft Work Statements

Program plans

IEA Annex 34 update

Other FDD research activities

5. SBS Applications Subcommittee Report (John House)

Status of Work Statement entitled "Demonstration of Fault Detection And Diagnostic Methods in A Real Buildings"

Draft Work Statements

Program plans

Philip Burton Office Building update

Iowa Energy Center update

Other possible demonstration sites

6. Utility/Bldg. Interface Subcommittee Report (Steve Blanc)

TRP - 1011, "Utility/EMCS Communication Protocol Requirements"

Draft Work Statements

Program plans

Real time pricing/Deregulation update

ASHRAE's role - discussion

7. Research Subcommittee Report (Jim Braun)

Work Statements

1998-99 Research Plan

8. Program Subcommittee Report (Carol Lomonaco)

Plans for San Francisco

Plans for Toronto

Plans for future meetings

9. New TG4.SBS 1998 Roster

10. Additional old business

11. Additional new business

12. Adjournment

Appendix B.

TG4.SBS Fault Detection and Diagnostics Subcommittee Meeting

Minutes

Boston: June 29, 1997

1. The first item of business was a discussion of a work statement entitled "FDD Requirements and Evaluation Tools for Centrifugal Chillers." The work statement was co-authored by Jim Braun and Arthur Dexter. Jim Braun provided a summary of the work statement, which focuses in part on identifying important centrifugal chiller faults, and developing and validating a simulation model of normal and faulty operation of a centrifugal chiller. The simulation model would be used in future research projects to develop FDD methods for centrifugal chillers.

A discussion of the estimated cost of the project ($150,000) and the restriction of the work statement to centrifugal chillers ensued. There was concern that the work statement would be rejected by the Research Administration Committee due to the cost. Others felt that the estimated cost was reasonable and that it did not need to be changed.

Phil Haves questioned whether this project could be performed using another type of chiller (e.g., a chiller with a screw compressor). Chillers with screw compressors tend to be smaller; therefore, the cost would be reduced and the competition for the contract increased. John Mitchell questioned the availability of modeling information for compressors other than the centrifugal type. It was noted that models of centrifugal chillers are in existence. More discussion on this subject followed. Other issues that were brought up included whether or not the study had to be conducted in a laboratory, and the need for some clarification of the use of the term "dynamic models."

Jim Braun will revise the work statement to address these issues and will have the new version of the work statement ready for the full committee meeting on Tuesday, July 1. The overwhelming majority of the attendees were in favor of passing on the revised work statement to the full committee with the recommendation that the full committee approve the work statement.

2. The second item of business was a discussion of ideas for new research work statements. Phil Haves brought up the subject of FDD at the

so-called middle level of the "top-down" and "bottom-up" FDD architectures. An example of middle level FDD might be identifying components that are operating when they should not be, or not operating when they should be. Phil Haves will write up a one-page description of a research project on this topic.

Jeff Haberl discussed the need for analytical redundancy models for faulty sensors. He will write a one-page description of a research project on this topic.

Submitted by:

John House

Appendix C.

TG4.SBS Applications Subcommittee Meeting

Minutes

Boston: June 29, 1997

John House distributed a draft work statement titled "Integrated Control for Building Services" written by Ron Kammerud and John Mitchell.

Ron Kammerud discussed project background, objectives and scope. Overall feeling among group was that the draft was written too loosely. The number and type of building should be specified as well as the number and type of building systems to be included in the project. Better to tightly specify details in RFP. In addition, the PMS should approve the selected set of buildings. Excellent question to ask owners would be what would you do differently and how much more are you willing to pay? Perhaps add BACnet interaction information. In some countries, integration standards are part of governing codes. Comments on the work statement should be sent to Kammerud.

Ron Kammerud described a second work statement titled "Scoping Study: Operation Dynamics Of Aggregates Of Buildings." Background and different phases were discussed. General consensus was that tools developed for this project should have ability to adjust parameters and should employ some type of artificial intelligence ("smart knobby tools"). Work statement should be more specific on tool requirements. End tool should be developed with the building owner and engineer in mind and not necessarily the utility production company.

Submitted by:

Margaret Bailey

Appendix D.

TG4.SBS Building/Utility Interface Subcommittee Meeting

Minutes

Boston: June 29, 1997

1. The first item of business was a discussion of program events at Boston and San Francisco related to Building/Utility Interface issues. A seminar entitled "The Utility/Building Interface: Redefining an Old Relationship" will be held Tuesday. Doug Nordham will try to pull together a seminar on the subject of real-time pricing for the San Francisco. Other ideas for B/U Interface programs were solicited. There was considerable discussion of the need for more information on the topic of deregulation. It was suggested that a seminar be put together featuring ESCO representatives talking about what services they might provide to clients, and large customers talking about what services they are looking for after deregulation. A proposed title for the seminar is "How and What Services Might be Delivered Under Deregulation."

2. The second item of business was a discussion of TRP 1011 "Utility/Energy Management and Control System (EMCS) Communication Protocol Requirements." Les Norford gave an overview of the work statement. The Proposal Evaluation Committee is to meet tomorrow to discuss the TRP and select a contractor.

3. The third item of business was a discussion of the goals, scope, and purpose of the Building/Utility Interface Subcommittee. Steve Blanc led the discussion. Issues of concern to this subcommittee were identified as:

• Protocols

• The marketplace

• Information transfer (content/process)

• Relationships between customers and utility vendors

• Systems integration

4. The fourth item of business was a discussion of ideas for new research work statements. Doug Nordham asked whether there is research in the area of distributed power generation that the TG could sponsor. No clear actions were defined from the discussion.

Submitted by:

John House

Appendix E.

TG4.SBS PROGRAM SUBCOMMITTEE

JULY 1, 1997, REVISION 1.0

Program Chair: Carol Lomonaco

The TG4.SBS Program Subcommittee meeting was called to order at 5:30 pm on 6/29/97 and ended at 6:33 pm on Sunday, June 29, 1997.

Attendees were:

George Kelly Carol Lomonaco John House Steve Blanc Pornsak Songkakul

Stephen Yang Doug Nordham Bob Old Les Norford Phil Haves

Todd Rossi Curtis Klaassen Jim Gartner Carlos Haiad Osman Ahmed

Michael Kintner-Meyer John Phelan Michael Brambley Hanjin Miao

Programs for Boston were noted as well as the programs for San Francisco, Toronto, Chicago, Seattle, and the future. Each of the six sections is provided below and the program information that was discussed and agreed upon in Sunday's meeting is noted. The program was approved at Tuesday's general meeting for TG4.SBS and this report reflects any changes in the general TG meeting (the changes are denoted by an asterisk (*)).

A program plan will be submitted Wednesday, July 2, 1997. [Other applicable co-sponsoring committees will be sought by Carol Lomonaco within the next 30 days.]

I. PROGRAMS ARE SCHEDULED FOR THIS MEETING IN BOSTON, JUNE 27-JULY 2, 1997

1. Sponsoring Committee: BACnet & Co-Sponsoring Committee: TC1.4 & TG4.SBS

BACnet in the Real World

Seminar 24, Tues., July 1, 1997, 8:00 - 10:00am, Adams (7th), Westin

2. Sponsoring Committee: TG4.SBS

The Utility/Building Interface: Redefining an Old Relationship

Seminar 35, Tues., July 1, 1997, 10:15 - 12:15pm, America Center (4th), Westin

3. Sponsoring Committee: TC1.4 & Co-Sponsoring Committee: TC1.5, TC4.6 & TG4.SBS

Exactly What Do Smart Buildings and Control Systems Mean Today?

Forum 30, Weds., July 2, 1997, 8:00 - 8:50am, Daniel Webster (7th), Westin

II. PROGRAMS PROPOSED FOR THE MEETING IN SAN FRANCISCO, JANUARY 17-21, 1998

1. Sponsoring Committee: TC1.4 & Co-Sponsoring Committee: TC1.2, TC4.6, TC1.9 & TG4.SBS

Impact of Electromagnetic Interference on Control Systems and Emerging Global Standards

Seminar, Jim Coogan

2. Sponsoring Committee: TC1.4 & Co-Sponsoring Committee: BACnet & TG4.SBS

Benefits of Interconnections with Other Non-HVAC Sub-systems

Seminar, Mike Newman

3. Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC9.6, TC1.10, TC4.6, TC4.7

The Delivery of New Energy Services Under Electric Industry Deregulation

Seminar, Doug Nordham

4. Sponsoring Committee: TC1.4 & Co-Sponsoring Committee: BACnet & TG4.SBS

Now That We Have a Protocol Standard, Are Applications and Programming Next?

Forum, Clay Nesler

5.* Sponsoring Committee: TC1.4 & Co-Sponsoring Committee: TC1.7, TC4.6, TG4.SBS

Who Really Determines Tomorrow's Buildings Indoor Environment Control, IAQ and Productivity-Designers, Installers or Operators?

Forum-Panel , Jim Gartner

6.* Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC1.4

Automated Response to Real Time Pricing (RTP)

Seminar, Kammerud (Carol Lomonaco will ask D. Matisak to participate.)

7. Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC1.4

Occupant Driven Interactive Building Control (a.k.a. The Building as an Interactive System)

Forum, Barry Bridges (Confirmed with Barry Bridges on June 30, 1997.)

III. PROGRAMS PROPOSED FOR THE MEETING IN TORONTO, JUNE 18-25, 1998

1. Sponsoring Committee: TC1.4 & Co-Sponsoring Committee: BACnet & TG4.SBS

CAB and BACnet Similarities and Dissimilarities

Forum, Mike Newman

2. Sponsoring Committee: TC1.4 & Co-Sponsoring Committee: TG4.SBS

The Latest Control Communications Technologies

Seminar, Jim Gartner

3. Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC1.4

Fault Detection Diagnostics Using Real Building Operating Data

Symposium, Phil Haves & Osman Ahmed

4. Sponsoring Committee: TC1.4 & Co-Sponsoring Committee: TG4.SBS

Controlling Outdoor Air Ventilation for 62-1989

Symposium, Rad Ganesh [3 papers](Jim Gartner will give an update at San Francisco)

IV. PROGRAMS PROPOSED FOR THE MEETING IN CHICAGO, JANUARY

23-27, 1999

1.* Sponsoring Committee: TC1.4 & Co-Sponsoring Committee: BACnet & TG4.SBS

Updates on Motor and Intelligent Actuators and Sensors

Seminar, Nebil Ben-Aissa, Jim Gartner & Rick Eiden (See Note 1 on page 4.)

2.* Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC1.4

What Is the Status of Smart Buildings and Where Are They? Asia? Europe? Singapore?

(What Are the Standards for Communications in Smart Buildings?)

Seminar, Michael Kintner-Meyer, (Carol Lomonaco will contact Moult & Cronin.)

3. Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC1.4, TC1.7

FDD, Soliciting Input From Operators and Owners Concerning Their Priorities. How Do They Rank Faults?

Seminar, Todd Rossi (Carol Lomonaco will help and solicit BOMA involvement.)

V. PROGRAMS PROPOSED FOR THE MEETING IN SEATTLE, JUNE 19-23, 1999

1. Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC1.4, BACnet

Three Different Levels of Fault Detection Diagnostics (FDD) and Their Integration.

(Level 1: Building Level (highest), Level 2: Component or Subsystem, Level 3: Control Loop)

Seminar, Todd Rossi

2. Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee:

What's ASHRAE's Role in Deregulation?

Forum, Steve Blanc

3. Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC9.9, TC1.4

Commissioning as a Base for Fault Detection Diagnostics (FDD)

Seminar, Doug Nordham, Phil Haves, Arthur Dexter, and Steve Yang

3.* Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC9.9, TC1.4

Implementing Fault Detection Diagnostics (FDD)in Real Systems (ANNEX 34)

Symposium, Phil Haves and George Kelly

VI. PROPOSED FUTURE PROGRAM SUBJECTS (UNPRIORITIZED):

1. Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC1.4

Do Smart Buildings Need More Sensors and Control Devices Than Dumb Ones?

Forum or Seminar, Carol Lomonaco

2.* Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC1.4

What Is The Definition of a Smart Building System? (Some Countries Have a Different Definition of What a Smart Building Is.)

Forum or Seminar, George Kelly and Jim Yi

3. Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC1.4

Are Smart Buildings using raised floors?

Seminar, Carol Lomonaco

4. Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC1.4

Deregulation and Energy Efficiency in the United States? Energy Efficient Independent Board (EEIB)?

Seminar, Les Norford & Carlos Haiad

5. Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC1.4

Case Studies of RTP and Aggregation in Maine, Massachusetts and WALMART & HOME DEPOT

Seminar, Les Norford, Steve Blanc, John Phelan & Doug Nordham

6. Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee: TC1.4

Fault Detection Diagnostics for Chillers

Symposium, Jim Braun, Todd Rossi

7. Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee:

Customers View of Deregulation

Seminar, Charles Claar (IFMA) & Jim Yi (Jim will contact Shikori & Laurret.)

8. Sponsoring Committee: TG4.SBS & Co-Sponsoring Committee:

ANNEX 34 Paper---an Update

Seminar/Symposium, Kelly, Braun & Haves

Note1: Jim Gartner combined #1 and #3 into the new #1 under section IV immediately after the general TG meeting to reflect the latest from TC1.4.

Appendix F.

List of Subcommittee Attendees

Name	FDD	Applications	Building/Utility Interface	Program
George Kelly	x	x	x	x

John Mitchell		x	x	
Les Norford	x	x	x	x
Jim Braun		x	x	
Philip Haves	x	x		
Carol Lomonaco	x	x	x	x
Steve Blanc			x	
Ron Kammerud	x	x		
Michael Kintner-Meyer		x		
Doug Nordham	x	x	x	x
John House	x	x	x	x
J. Carlos Haiad	x	x	x	x
Jim Winston	x			

Osman Ahmed	x	x	x	x
Margaret Bailey	x	x		
Mike Brambley	x	x	x	x
Natascha Castro	x			
Fred Cogswell	x			
Paul Duff	x			
Barrett Flake	x			
James Gartner				x
Jeff Haberl	x	x	x	
Rich Hackner	x	x	x	
Kristin Heinemeier	x			
Brian Kammers	x	x	x	

Kevin Keeney	x	x		
Curt Klaassen	x	x		
Hanjin Miao	x	x	x	x
Ron Nelson	x			
John Phelan	x		x	
Todd Rossi	x	x	x	x
Pornsak Songkakul			x	x
Gene Strehlow		x	x	
Steve Yang		x	x	

Appendix G.

TG 4.SBS, Smart Building Systems

Long-Range Research Plan for 1997-1998

August, 1997

Prioritized list of work statements being developed

1. Fault Detection and Diagnostic Requirements and Evaluation Tools for Chillers
2. Integrated Building Services - Performance and Performance Measurements
3. Distributed and Hierarchical Fault Detection and Diagnosis of HVAC Systems
4. Optimizing EMCS Architecture in BACnet Speaking Systems
5. Development and Evaluation of Fault Detection and Diagnostic Methods for Chillers
6. Development of Fault Detection and Diagnostics for Sensor Failures

Task Group 4.SBS, Smart Building Systems

Research Project Description

Priority 1

Project Title: Fault Detection and Diagnostic Requirements and Evaluation Tools for Chillers

Summary: A significant portion of the energy and maintenance costs for operating commercial HVAC systems is associated with chillers. Current chiller fault detection and diagnostic (FDD) systems focus on preventing catastrophic failures by shutting defective systems down. Although there is a large body of literature on fault detection and diagnostic (FDD) techniques for applications in critical processes, very little has been published for chillers. The proposed project would focus on developing the tools and data necessary to evaluate the performance of alternative FDD techniques. The most important faults to be considered will identified, a model will be developed and validated for simulating normal and faulty performance, and experimental data will be collected for normal and faulty chiller behavior. The development and evaluation of FDD methods would occur in a future project using the information and models resulting from this project.

Objective: To develop tools and data that will be used in the development and evaluation of FDD methods applied to chillers.

Benefits: Automated fault detection and diagnostics (FDD) for HVAC systems have the potential to reduce energy and maintenance costs and improve comfort and reliability. Inadequate maintenance can lead to inefficient operation (energy costs), a loss in cooling capacity (comfort), and

increased wear of components (reliability). However, too much maintenance leads to excessive maintenance costs. In addition, early diagnosis of equipment problems using remote monitoring techniques can reduce the costs associated with repairs by improving scheduling and reducing on-site labor time.

Estimated Cost: $145,000

Estimated Duration: 24 months

Methods of Publishing Results

1. Detailed Reports
2. Technical Paper(s)

Potential Cosponsors:

1. chiller manufacturers
2. chiller service providers

Task Group 4.SBS, Smart Building Systems

Research Project Description

Priority 2

Project Title: Integrated Building Services - Performance and Performance Measures

Summary: The integration of the control of multiple building services, such as HVAC, fire, security, and transportation, offers the building owners and operators many benefits and some possible problems. Unfortunately there has been no systematic research to evaluate and document the pro and cons of integration, nor to examine the different methods by which it may be achieved. This study will examine different levels of integration in commercial office buildings, including no integration, the use of a single network by different building systems (token integration), full integration using a building management system from a single vendor, and different vendor supplied building systems using a common communication protocol, such as BACnet. The benefits and problems associated with each approach will be carefully documented. In addition, various performance measures will be developed to compare the safety, reliability, comfort, cost, energy consumption, ease of use, maintenance requirements, etc. of the different approaches.

Objectives:

1. To examine different approaches to the integration of building services in a variety of commercial office buildings.
2. To evaluate and document the pros and cons associated with each approach.
3. To develop performance measures that can be used by building designers, owners, and operators for comparing different levels of integration and for selecting the best approach for a given application.
4. To develop recommendations for future research in this area.

Benefits: This research will provide valuable information on the benefits and problems associated with the integration of building services. The development of performance measures for comparing different approaches should significantly improve the decision making process for building designers, owners, and operators. In addition, this work is likely to lead to the future development of ASHRAE Guidelines on evaluating and choosing the best approach to integrating building services in different applications.

Estimated Cost: $80K

Estimated Duration: 12 months

Methods of Publishing Research Results:

1. Detailed Reports
2. Technical Paper(s)

Task Group 4.SBS, Smart Building Systems

Research Project Description

Priority 3

Project Title: Distributed And Hierarchical Fault Detection and Diagnosis of HVAC Systems

Summary: A variety of different fault detection and diagnostic (FDD) methods have been studied (by IEA Annex 25 and others) and applied to HVAC systems using either simulation or laboratory test rigs. It was found that each of the methods appear to have different strengths and weaknesses. Thus, future FDD systems installed in actual buildings are likely to employ a number of different FDD methods on the same HVAC subsystem, different HVAC subsystems, and at different levels within a building s energy management and control system (EMCS). How the results from all these different FDD applications are coordinated, integrated, evaluated, and how conflicts are resolved and information presented to the

operator in an intelligent manner needs to be addressed. This research will attempt to do this for an VAV distribution system (excluding the heating/cooling plant) in a typical office building employing a distributed EMCS.

Objectives:

1. Select 7 or more promising methods for performing FDD on an VAV distribution system using a distributed EMCS in a typical office building.
2. Examine different approaches for applying these multiple methods to the same and different subsystems and at different control levels within the EMCS
3. Examine different approaches for coordinating, integrating, evaluating, and presenting the resulting information to the building operator.
4. Select several of the most promising FDD system architectures and implement them sequentially in a typical office building that has been approved by the Project Monitoring Committee.
5. Evaluate and document the benefits and problems associated with each approach and recommend one or more preferred distributed/hierarchical FDD architectures for use in office building HVAC applications.

Benefits: A better understanding of the different approaches for integrating FDD methods in a distributed and hierarchical manner will accelerate the development and implementation of FDD systems in buildings. This in turn should lead to improved HVAC performance, reduced energy consumption, and lower operating and maintenance costs.

Estimated Cost: $120K

Estimated Duration: 16 months

Methods of Publishing Research Results:

1. Detailed Reports
2. Technical Paper(s)

Task Group 4.SBS, Smart Building Systems

Research Project Description

Priority 4

Project Title: Optimizing EMCS Architecture In BACnet Speaking Systems

Summary: BACnet - A Data Communication Protocol for Building Automation and Control Networks (ASHRAE Standard 135-1995) was

approved by ASHRAE in June 1995 and by ANSI in December 1995. To date, several hundred BACnet speaking EMCS have been installed around the world and the pace of such installations is expected to accelerate rapidly as more and more BACnet products become available. The BACnet standard is extremely flexible and allows the EMSC designer to specify different levels of functionality for different control devices. While this flexibility is in general good, it can cause problems when using BACnet to integrate control system components from different manufacturers. If different control manufactures take different approaches to the distribution of these communication functions among the various levels within an EMCS, it could impact how well control devices at the same (or different) levels can work together. In addition, important issues relating to how different EMCS architectures effect network message traffic, security, and the performance of the building/HVAC/control system need to be addressed.

Objective:

1. Select several commercial buildings with BACnet speaking EMCS that employ a variety of different EMCS architectures and different approaches to distributing intelligence (functionality) among sensors, unitary controllers, field panels, and work stations.
2. Evaluate the pros and cons of each architecture from the point of view of network message traffic and response time, security and access, reliability and stand alone capability, control system performance, ease of expansion, software development and maintenance, etc..
3. Document the results of the above work and recommend one or more standard architectures for BACnet speaking EMCS that optimize most or all of the above performance measures. If a variety of solutions existing depending on application, provide guidelines for designers that will assure proper EMCS performance while minimizing control system interfacing and expansion problems.

Benefits: It is important to the building industry and to ASHRAE to have the BACnet Communication Protocol adopted and implemented in both new and old EMCS.. This research will help assure that BACnet speaking control system components from different manufacturers will be able to interface at all control levels with optimal performance and a minimum number of problems.

Estimated Cost: $70K **Estimated Duration:** 12 months

Methods of Publishing Research Results:

1. Detailed Reports 2. Technical Paper(s)

Task Group 4.SBS, Smart Building Systems

Research Project Description

Priority 5

Project Title: Development and Evaluation of Fault Detection and Diagnostic Methods for Chillers

Summary: The goal of the proposed project is to develop and evaluate methods for real-time detection and diagnosis of typical faults that occur in chillers. In a phase I ASHRAE project, tools and data will be developed that would be used in this project. Based upon the results of literature reviews, surveys, and sensitivity studies from phase 1, a list of faults and preliminary FDD methods will be identified. A simulation model and measured chiller performance data for both normal and faulty behavior developed in phase I will be used in the phase II project to evaluate the FDD methods and develop improvements. Steps in this project will include: 1) development of a procedure for evaluating the performance of alternative FDD methods (e.g., performance indices could include the minimum detection and diagnostic sensitivity for different faults and the likelihood of false alarms), 2) assessment of existing FDD methods through simulation and use of experimental data, 3) evaluation of the impact of number and accuracy of sensors on FDD performance, and 4) development of FDD improvements, and 5) recommendations for an field implementation of the most promising FDD methods (a phase III project).

Objective: The development and evaluation of algorithms that could be used to detect and diagnose common faults in chillers.

Benefits: Automated fault detection and diagnostics (FDD) applied to chillers used in air conditioning of commercial buildings has the potential to reduce energy and maintenance costs and improve comfort and reliability. Although current control systems typically monitor many variables, this information is not used for diagnosing faults. At best, these systems incorporate automatic shutdown procedures that guard against catastrophic failures when measurements are extremely out of range.

Estimated Cost: $80,000

Estimated Duration: 18 months

Methods of Publishing Results

1. Detailed Reports
2. Technical Paper(s)

Potential Cosponsors:

1. chiller manufacturers'
2. chiller service providers

Task Group 4.SBS, Smart Building Systems

Research Project Description

Priority 6

Project Title: Development of Fault Detection and Diagnostics for Sensor Failures

Objective: The objective of this research is to develop Fault Detection Diagnostics (FDD) for detecting failed sensors of the type that are typically used in HVAC systems, including: temperature sensors, electricity sensors and flow sensors. Examples of known FDD sensors techniques include: high-low limit comparisons, model comparisons, sensor redundancy, and analytical redundancy. This work would be beneficial to implementing Fault Detection Diagnostics that are dependent on the accurate data from a suite of sensors.

Scope: This research includes: (1) Thorough literature search into the current methods that are used to detect sensor failures of the type that typically used in HVAC systems, (2) development of a suite of FDD procedures for HVAC sensors, (3) testing and verification of the developed FDD procedures on specially prepared data from sensors that contain known faults.

Benefits: The project will benefit ASHRAE membership as well as the general public as follows:

1. ASHRAE to develop methods to detect fault diagnostics in sensors.
1. Equipment suppliers as an aid for incorporating FDD techniques into equipment.
1. Text book publishers for documenting such methods.
1. ASHRAE for developing more effective training programs for teaching engineers and architects how to apply FDD methods to sensors.
1. Improving energy efficiency by providing ASHRAE members with improved methods for sensor FDD.

Estimated Cost: $75,000

Duration: 18 months

Appendix H.

Workstatement

TG 4.SBS, Task Group on Smart Building Systems

PROJECT TITLE

Fault Detection and Diagnostic (FDD) Requirements and Evaluation Tools for Chillers

BACKGROUND

Automated fault detection and diagnostics (FDD) for HVAC systems has the potential to reduce energy and maintenance costs and improve comfort and reliability. Inadequate maintenance can lead to inefficient operation (energy costs), a loss in cooling capacity (comfort), and increased wear of components (reliability). However, too much maintenance leads to excessive maintenance costs. In addition, early diagnosis of equipment problems using remote monitoring techniques can reduce the costs associated with repairs by improving scheduling and reducing on-site labor time.

There is a large body of literature on fault detection and diagnostic techniques for applications in critical processes. As the cost of hardware (e.g., sensors, micro-processors) has gone down, interest in developing FDD systems for HVAC&R applications has increased. Most of the literature for HVAC&R applications has focused on "hard" failures for large central chilled water distribution systems and air handling systems. Recently, several FDD techniques for HVAC applications were developed and evaluated through the International Energy (IEA) Annex 25 (Hyvarinen, et. al). The literature for fault detection and diagnosis for vapor compression equipment is relatively sparse but includes contributions by McKellar (1987), Stallard (1989), Yoshimura and Noboru (1989), Kumamaru et al. (1991), Wagner & Shoureshi (1992), Hiroshi et al. (1992), Grimmelius et al. (1995), and Rossi & Braun (1996, 1997).

Of these studies, only Grimmelius investigated FDD for chillers. In this work, Grimmelius et al. (1995) used differences between measurements and outputs of steady-state models for expected behavior as input features for detection and diagnoses of chiller faults. The method used approximately 20 measurements, including temperatures, pressures, power consumption, and compressor oil level. Diagnoses were performed using a pattern recognition technique applied to the current residuals and a matrix of expected residual changes associated with each possible fault. The fault matrix was determined using experiments on a chilled water system in which faults were introduced. The use of system specific fault models requires extensive experimentation for each possible fault, particularly when performance degradation faults are considered. Furthermore, this study did not include an evaluation of 1) the sensitivity of the FDD method in detecting and diagnosing faults, 2) the impact of number and type of sensors, and 3) alternative FDD techniques. Much more work is necessary before FDD is widely applied to chillers.

The development and evaluation of a FDD method for any application should follow a systematic process that involves the use of computer simulations, laboratory experiments, and field studies. The following steps illustrate one approach to the development and evaluation of a FDD method for a particular application.

Step 1: Identify the important faults to consider through an evaluation of service records for the application.

Step 2: Develop a simulation of the system that can predict both normal and faulty performance.

Step 3: Use the simulation model to generate data for normal and faulty behavior over a wide range of operating conditions.

Step 4: Use the simulation data for both "training" the FDD algorithm and for evaluating its performance. Typically, performance would be measured in terms of minimum sensitivity for detecting each fault in the absence of any false alarms. The impact of the number and quality of sensors on performance could be evaluated in this step in order to identify the sensor requirements. In this step, the performance of alternative FDD methods could be evaluated and the "best" methods could be considered for laboratory and/or field evaluation.

Step 5: Install the system in a laboratory environment and add the necessary sensors identified in step 4.

Step 6: Perform both steady-state and transient tests on the system over a range of operating conditions and fault levels.

Step 7: Use the measured performance data for both "training" the FDD algorithm and for evaluating its performance. The "snapshots" of transient performance for different conditions could be "played back" through any FDD algorithm in order to evaluate and improve its performance. Performance could be measured in terms of minimum sensitivity for detecting each fault in the absence of any false alarms.

Step 8: Perform field tests of the FDD algorithm for a number of installations in order to obtain a "rich" set of data regarding the performance of the FDD method.

The scope of steps 1 - 8 is beyond what could be accomplished within a single ASHRAE project. The proposed project would focus on developing the tools and data necessary to evaluate the performance of alternative FDD techniques (steps 1-3 and 5-6) applied to chillers. The evaluation of FDD techniques for chillers would occur in a future project.

JUSTIFICATION OF NEED

A significant portion of the energy and maintenance costs for operating commercial HVAC systems is associated with chillers. Although current control systems typically monitor many variables, this information is not used for diagnosing faults. At best, these systems incorporate automatic shutdown procedures that guard against catastrophic failures when measurements are extremely out of range.

Although there is a large body of literature on fault detection and diagnostic techniques for applications in critical processes, very little has been published for vapor compression equipment. In particular, research is needed to develop on-line methods for detecting and diagnosing common faults in chillers. Reliable FDD methods for chillers will reduce both energy and maintenance costs.

OBJECTIVES

The overall objective of this project is to develop tools and data that will be used in the development and evaluation of FDD methods applied to chillers. The study will be limited to either screw or centrifugal chillers with continuous capacity control and water-cooled condensers. The bidder will specify the type (either screw or centrifugal) and size of chiller to be considered. For both screw and centrifugal chillers, the most important faults to be considered will identified. For the selected chiller type, a model will be developed and validated for simulating normal and faulty performance, and experimental data will be collected for normal and faulty chiller behavior. The deliverables from this project will be used in a future project in the evaluation of alternative FDD techniques.

SCOPE

As implied by the stated objectives, the scope of the project involves both simulations and experiments. It is expected that the experimental work will be performed in a laboratory or laboratory like environment with a well instrumented chiller in which faults can be introduced. All bidders are expected to propose and describe the type and size of chiller to be considered, the experimental setup to be used for the project, and the tests to be performed. The contractor will use the measurements to validate the simulation model. In addition, the measurements will be a deliverable that will be used in a future project. The simulation model will be used by the contractor to evaluate the sensitivity of chiller performance to faults.

The following specific tasks will be performed:

Task 1: Review previous work

Perform a literature review and industry search for currently implemented and proposed methods for fault detection and diagnostics that could be applied to chillers. The contractor should begin with the literature referenced in this workstatement. In addition, a literature search will be carried out on physical models for chillers that could be used in the development and evaluation of FDD methods. The literature survey should include publications for both screw and centrifugal chillers. Bourdouxhe et al. (1996) provide a comprehensive overview of literature related to dynamic modeling of vapor compression equipment that could be used as a starting point. The reviews should be performed during the first four months of the project and reported at the first review meeting with the PMS. The results of the reviews should be summarized in a short report prepared following the first review meeting and prior to the second review meeting with the PMS.

Task 2: Identify important faults

A survey will be performed to identify the most important faults for both screw and centrifugal chillers. The information collected should include the frequency of occurrence and the total annual costs associated with the repair of each fault. The survey is not meant to be a comprehensive study and should be performed during the first four months of the project and reported at the first review meeting with the PMS. The contractor should attempt to obtain this information from one or two equipment manufacturers' and/or service providers. If this information is not obtainable from these sources,

the contractor may use service records from a limited number of large facilities (e.g., college campuses, airports, large commercial complexes) that utilize screw or centrifugal chillers. The results of the survey should be summarized in a document prepared following the first review meeting and prior to the second review meeting with the PMS.

Task 3: Develop simulation model

A physical model for the proposed chiller type (screw or centrifugal) will be developed. The model should be capable of predicting the effects of the important faults on system performance, including refrigerant leakage, and condenser and evaporator fouling. In order to evaluate FDD methods that require steady-state detection algorithms or that utilize dynamic information, the model should consider the important system dynamics. In particular, the dynamics associated with refrigerant migration and thermal energy storage in the heat exchangers and compressor should be considered. The model should be able to adequately predict the time evolution of refrigerant states in response to changes in chilled water setpoint, return temperature, and flow and condenser water supply temperature and flow. It is believed that the chiller model can be developed primarily using models that are already described in the literature. Bourdouxhe et al. (1996) provide a comprehensive overview of literature related to dynamic modeling of vapor compression equipment. The bidder should provide a fairly detailed description of the modeling approach that will be followed. In addition, the bidder should describe in detail how this model would be interfaced in the second phase project with other computer programs that perform on-line fault detection and diagnostics. The interface should allow communication of operating conditions, fault levels, and refrigerant states. Note that the accuracy of the model in predicting actual performance is not as important as its ability to predict the correct trends associated with the introduction of faults and changing operating conditions.

Task 4: Acquire chiller data

Data will be obtained for a screw or centrifugal chiller from a laboratory or laboratory like setup. The experimental facility should allow the introduction of the faults to be considered in a reproducible manner and under reproducible operating conditions. In addition to any faults identified in Task 2, the facility should allow the emulation of the following faults: 1) refrigerant leakage or overcharging, 2) condenser fouling, 3) evaporator fouling, and 4) stuck expansion device. Measurements should be sufficient to characterize: 1) the states of refrigerant and water entering and leaving each component (e.g., heat exchanger, compressor), 2) the chiller cooling capacity, 3) the compressor power consumption, and 4) the level of each fault to be introduced. The bidder will specify the type and size of chiller to be considered. However, the study will be limited to either screw or centrifugal chillers with continuous capacity control and water-cooled condensers. The contractor may choose to use an existing facility or install a new or rebuilt chiller. In either case, the proposal should contain a detailed description of the chiller, instrumentation, and methods to be used in introducing and characterizing faults (at least those outlined above). In addition, the proposal should contain a preliminary test plan that would be followed, including the levels of faults to be introduced. Both steady-state and transient data should be acquired for different combinations of faults and operating conditions. The contractor's final test plan will be reviewed and approved by the Project Monitoring Subcommittee prior to testing. The bidder should consult ASHRAE's SPC-150 regarding the accuracy of sensors to be used for the experimental setup.

Task 5: Validate simulation model

Measurements will be acquired and compared with model predictions over a range of steady-state and transient operating conditions under normal and faulty operation. The model should be improved, as necessary, to reduce modeling errors. The accuracy of the model in predicting actual performance is not as important as its ability to predict the correct trends associated with the introduction of faults and changing operating conditions.

Task 6: Perform fault sensitivity studies

The simulation model should be used to study the sensitivity of both steady-state and transient system performance (e.g., capacity, efficiency, refrigerant states) to the impact of different faults. This information could be useful in identifying the important measurements to use in detecting and diagnosing faults.

DELIVERABLES

1. Quarterly progress and financial reports.
1. Oral presentations of the Principal Investigator to the project monitoring subcommittee of TG 4.SBS at the annual and winter meetings.
1. A final report that summarizes the literature reviews, the survey of faults, the simulation model and its validation, the experimental setup and results, and the sensitivity studies.
1. Diskettes containing source code for the simulation model, the database of fault occurrences and costs, and the steady-state and transient chiller measurements.
1. A technical paper that describes the results of the survey on frequency of occurrence and cost of repair for chiller faults.
1. A technical paper that describes the chiller model and validation.

LEVEL OF EFFORT

It is estimated that the project will require approximately 24 months at a cost of about $145,000.

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AUTHORS

Jim Braun

Arthur Dexter

IMPORTANT INFORMATION FOR BIDDERS

The scope of this project is rather large. Proposals will be evaluated in terms of how well the bidders demonstrate an understanding of the relevant issues and describe the approaches to be followed in each task. In particular, the bidders should consider the following points in developing proposals.

1. The proposal should contain a detailed description of the chiller, instrumentation, and methods to be used in introducing and characterizing faults (at least those outlined above). In addition, the proposal should contain a preliminary test plan that would be followed.
2. The budget may not be sufficient to support the purchase and installation of a chiller. If a bidder does not have access to an appropriate chiller, then that bidder should consider contacting equipment manufacturers' or service providers to obtain the donation of a new or rebuilt chiller. Cost sharing by an industrial participant is strongly encouraged.
3. The bidder should clearly describe the approach that they will follow in performing the survey of chiller faults. This description should include the sources and expected number of chillers to be included, the length of the service records to be considered, and the type and presentation of information expected.
4. The bidder should provide a fairly detailed description of the chiller modeling approach that will be followed and how this model would be interfaced in the second phase project with other computer programs that perform on-line fault detection and diagnostics. The interface should allow communication of operating conditions, fault levels, and refrigerant states.